TIME-SHARING EFFECTS ON PILOT TRACKING PERFORMANCE

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TIME-SHARING EFFECTS ON PILOT
TRACKING PERFORMANCE

by

John Patrick Kennedy

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aircraft. Analysis of the data collected from 20 subjects showed that correlation between elements of a complex task is weak, performance levels drop as task load increases, and there was only one difference found between any of the pilot type groups. Dual-crew fighter/attack jet pilots took significantly longer to respond to stimuli when time-sharing.

Time-sharing Effects on Pilot Tracking Performance

by

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Lieutenant, United States Navy
B.S., United States Naval Academy, 1968

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Subjects were required to simultaneously perform a two-dimensional tracking task and respond to a set of lights with toggle switches. Five levels of difficulty and two stimulus presentation rates were involved in the secondary task. The purpose of the experiment was to examine time-sharing performance of experienced military pilots and to investigate differences in performance by pilots of different types of aircraft. Analysis of the data collected from 20 subjects showed that correlation between elements of a complex task is weak, performance levels drop as task load increases, and there was only one difference found between any of the pilot type groups. Dual-crew fighter/attack jet pilots took significantly longer to respond to stimuli when time-sharing.

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The constant help and guidance of these advisors often kept the methods and procedures from going astray. Mr. Cecil Gordon and Mr. Mike Odell of the Aeronautical Engineering Department, Naval Postgraduate School, Monterey, California, deserve special thanks for constructing special timers and circuits in the RED BARON simulator and for maintaining its precise capabilities.

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I. INTRODUCTION

Human factors engineering has been defined as "that branch of modern technology which deals with ways of designing machines, operations, and work environments so that they match human capacities and limitations" (Chapanis, 1959). An alternative definition considers human factors engineering as "that area of psychology primarily concerned with personnel subsystem interaction in a man-machine or man-environment system" (Waldeisen, 1974). In the past two decades systems designers and engineers have come to recognize the importance of the human operator as part of complex systems such as Naval air weapons systems. Consequently there has developed an appreciation for the necessity to consider human operator skills, abilities and limitations in the design of systems (Wilkens, 1973).

A pilot's task today requires a role as a complex system monitor and decision maker in addition to performing complex control movements. The more advanced air weapons systems designs currently being produced have necessitated the requirement for more sophisticated and qualitatively faster and better performance on the part of the human operator. These requirements have fostered the inclusion of disciplines such as human factors engineering as a viable input to complex system

development. However, a number of problems have surfaced in an effort to apply human factors engineering. A central issue which has received little attention is the problem of methodology necessary to measure complex system performance from the standpoint of human operator efficiency. Part of the problem originates with past tendencies to analyze human performance one variable at a time. There is a serious question concerning the appropriateness of such methodology to adequately assess complex, time-sharing performance as found in complex man-machine systems.

Time-sharing is defined as "the requirement (of a human operator) to divide his attention between two or more sources of information" (Gabriel and Burrows, 1968). It is difficult to imagine a situation which does not critically require time-sharing performance from the pilot of an aircraft. The simple task of flying a straight and level path involves (a) monitoring of several flight instruments and systems gages, (b) coordinated movement of arms and legs, and (c) monitoring radio information. Operational requirements may impose greater pilot task loading due to maneuvers, weather, and a myriad of tactical factors.

One can best appreciate the complexity of a military pilot's job by taking a novice's view of the cockpit in any military aircraft. The wall-to-wall array of gages, lights, dials, switches, and other controls can appear to be awesome.

Gabriel and Burrows (1968) demonstrated that it is possible to improve complex performance (specifically, time-sharing abilities) in pilots through training.

An understanding of a pilot's ability to time-share has potential applications in two major areas, systems design and training. Both applications depend upon appropriate methods for measuring human performance in time-sharing tasks. Questions about crew size, mission requirements, scenarios, proficiency, and training could be studied more objectively if such methodology were employed.

II. METHOD

A. DESIGN

All subjects received the same taped instructions, the same number of sessions, and all treatment conditions. Thus, each subject acted as his own control.

Subjects were categorized in four groups of five subjects each according to the type of operational aircraft each had flown. Group one was composed of single-person-crew jet pilots; group two was dual-person-crew jet pilots; group three was helicopter pilots, and group four was composed of propeller-driven aircraft pilots.

Subjects received learning sessions in both the tracking task and the secondary task, which was comprised of five levels of difficulty. Each subject in each group performed a time-sharing task consisting of the tracking task and each of the five levels of difficulty of the secondary task. Each subject performed the time-sharing tasks under two stimulus presentation rates.

The dependent variables for the study were tracking scores in each of the three different modes of time-sharing, total reaction time, and efficiency scores.

The two-dimensional tracking task required each subject to maintain a small dot of light close to the center of a cathode ray tube screen by manipulating a non-moving force stick (Figure 1). Each scoring run was 100 seconds long, and each subject's score per run

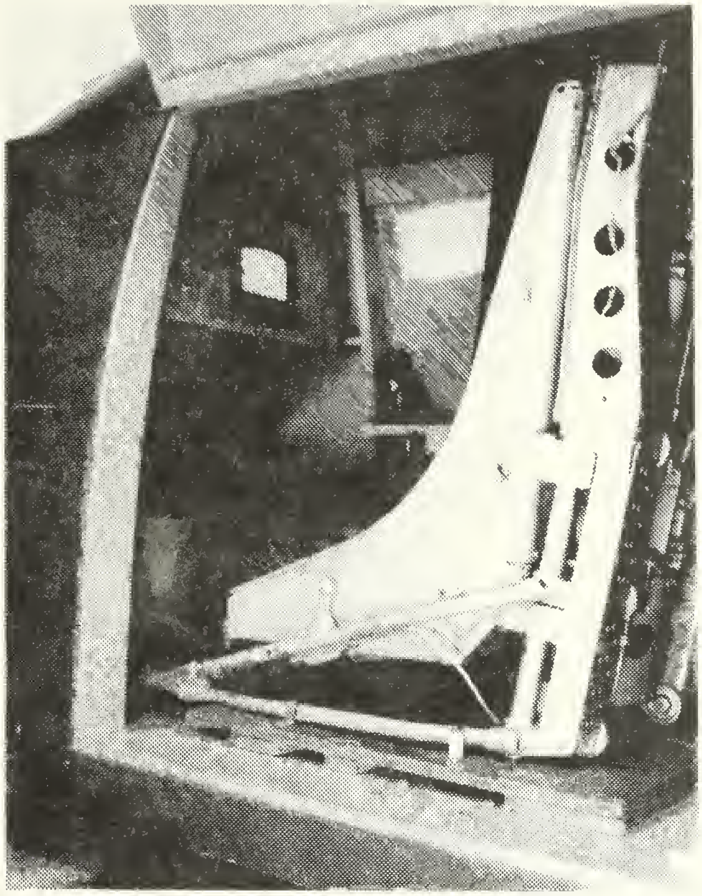

Figure 1. Test Subject Operating Station.

was the total number of seconds that he could keep the dot of light inside a 4-millimeter square at the center of the screen.

The secondary task in the study consisted of responding to one of five lights located on the left side of the display panel by turning the appropriate light off, using one of the five toggle switches located next to the lights (Figure 2). Five possible light/switch combinations (levels of difficulty) were possible. Figure 3 is an illustration of these five combinations. To the left of the figure is an illustration of the switches and lights on the display panel. The figure may be read as follows. Starting in the second column the light sequences are numbered. The first column is the switch. In light sequence 1, switch number 1 activates (or deactivates) light A. In light sequence number three, for example, switch number 2 activates light D. In addition to having five sequences the secondary task had two stimulus presentation rates. Under stimulus presentation rate ten (SPR10) a light would come on every ten seconds or a total of ten times per run. Under stimulus presentation rate twenty (SPR20) a light would come on every five seconds or a total of twenty times per run.

Subjects were given three learning sessions of seven runs each wherein they performed only the two-dimensional tracking task. Prior to commencing the first session the subject heard a taped explanation of testing procedures

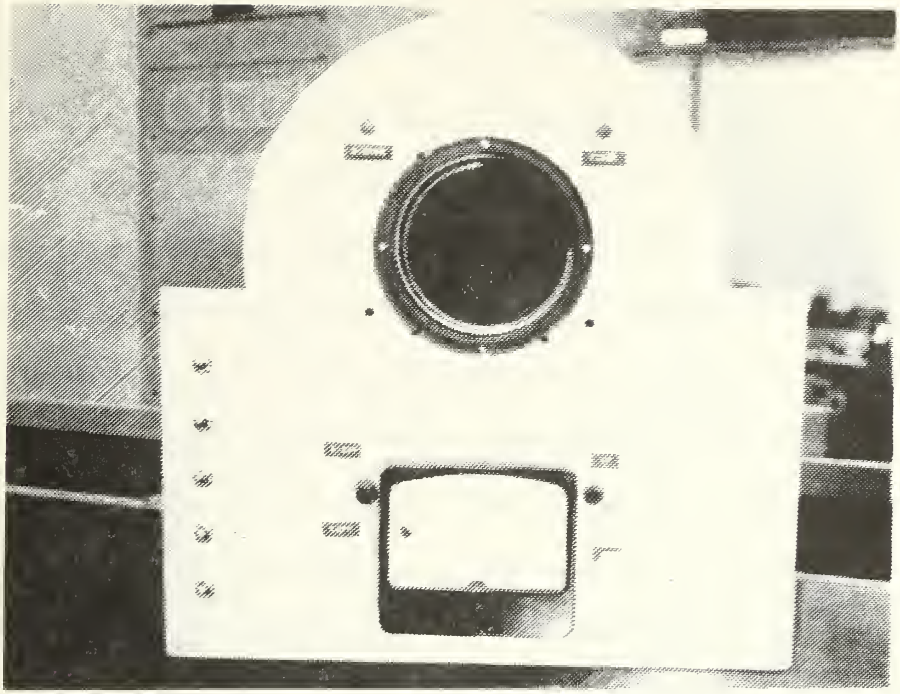

Figure 2. Display Panel.

Switch	Light
1	A
2	B
3	C
4	D
5	E

	Light Sequence				
Switch	1	2	3	4	5
1	A	B	C	D	E
2	B	C	D	E	A
3	C	D	E	A	B
4	D	E	A	B	C
5	E	A	B	C	D

Figure 3. Switch/light Combinations For Each Light Sequence.

(Appendix A). The entire first session was devoted to familiarizing the subject with equipment and procedures and to learning the tracking task. The only difference in procedures during the second and third sessions was that the subject was not required to listen to the taped instructions again. An indicant of a subject's performance level after learning the basic tracking task was obtained by averaging the final five runs in each of the second and third practice sessions. It was at that point that each subject was considered to be performing at his asymptotic level, i.e., the subject's increase in learning reached a negligible rate. This score was called the mean tracking score (MTS). The MTS was used as a base score. Deviations from the base score were used as indicants of the effects of mean tracking scores under time-sharing conditions.

Before commencing the fourth session each subject listened to another tape which explained the secondary task (Appendix B). The first run in this session involved only the two-dimensional tracking task. After the subject had scored in the range of his MTS, time-sharing testing began. During each of the ensuing ten runs the subject performed the tracking task and the secondary task simultaneously, i.e., in the time-sharing mode. The SPR/light sequence combinations were given in a predetermined and randomized order. The sequence in which stimuli were presented in each run were also predetermined and randomized.

Before each of the time-sharing runs began, the subject had up to 50 seconds to learn the light sequence (level of difficulty) for the following run. During those 50 seconds the subject was at liberty to turn lights on and off with the toggle switches and thus learn the light/switch combination for the following run. When he was informed that his 50 seconds had expired, he was required to place all the switches in the same position, i.e., either up or down.

Five tracking scores were averaged in SPR10 and SPR20, respectively, to obtain the subject's mean tracking scores under SPR10 (MTS10) and under SPR20 (MTS20). Total reaction time, herein defined as the total time (seconds) that any light was on during a run, was recorded with the number of incorrect responses made during the run.

Efficiency scores were the average of the sum of the total reaction time and the number of incorrect responses, multiplied by a constant which was derived by dividing the total number of mistakes made during time-sharing runs by the number of time-sharing runs completed. The constant was approximately 0.8. These averaged scores became the efficiency scores under SPR10 and SPR20.

B. SUBJECTS

The subjects for the experiment were twenty male students at the Naval Postgraduate School, Monterey,

California. The subjects were all designated Naval aviators with exactly one tour of operational experience. Subjects ranged in age from 26 to 31 years and averaged 29.6 years. The subjects had an average of 1425 total flight hours and had not flown operationally in an average of 1.6 years. Exactly 50% of the subjects had combat experience as pilots (four in group one and two in each of the other groups).

All subjects were volunteers and, with two exceptions, students in the Naval Postgraduate School Aeronautics Curricula. They were not compensated for their time, but were motivated by competition between groups and among individuals. Tracking scores and averages were posted periodically in a central area.

Subjects received a short explanation of the methods and goals of the experiment. Subjects asked few questions after testing began.

C. STIMULUS AND APPARATUS

The Research Education Device for Basic Aeronautics (RED BARON) provides a two-dimensional tracking task and a set of five lights and five switches to measure pilot performance in the tracking task and in time-sharing wherein test subjects perform both tasks simultaneously.

The RED BARON has six major components. These are listed in Appendix B.

Figure 1 shows the test subject's station which includes a salvaged FJ aircraft ejection seat, a

non-moving force stick, and a display panel. Closing a door to the test subject station activated a ventilator fan and a light which were included in the design for test subject comfort.

Figure 2 shows the display panel, the green scorer light, which illuminated whenever the test subject was "on target," and the blue timer light, which illuminated five seconds before and all during scoring runs, are located in the upper left and upper right hand corners, respectively. The cathode ray tube oscilloscope is located in the upper center of the panel, and the two knobs for adjusting the pipper position on the oscilloscope are located on either side of the airspeed display (a non-functional vestige of previous studies). Arranged vertically on the left side of the scope are the toggle switches and lights (components of the secondary task).

Figure 4 is a view of the entire test station including, from the left, a tape deck, an analog computer, the three counters, the experimenter's switches and lights, and the test subject's station.

Figure 5 is a closer view of the outside test station with all of the aforementioned equipment.

The tape recorder provides a repeatable test signal which is displayed on a five-centimeter square portion of the oscilloscope. The subject-operated force stick generates a signal which acts to cancel the random output signal from the tape, moving the displayed pipper toward

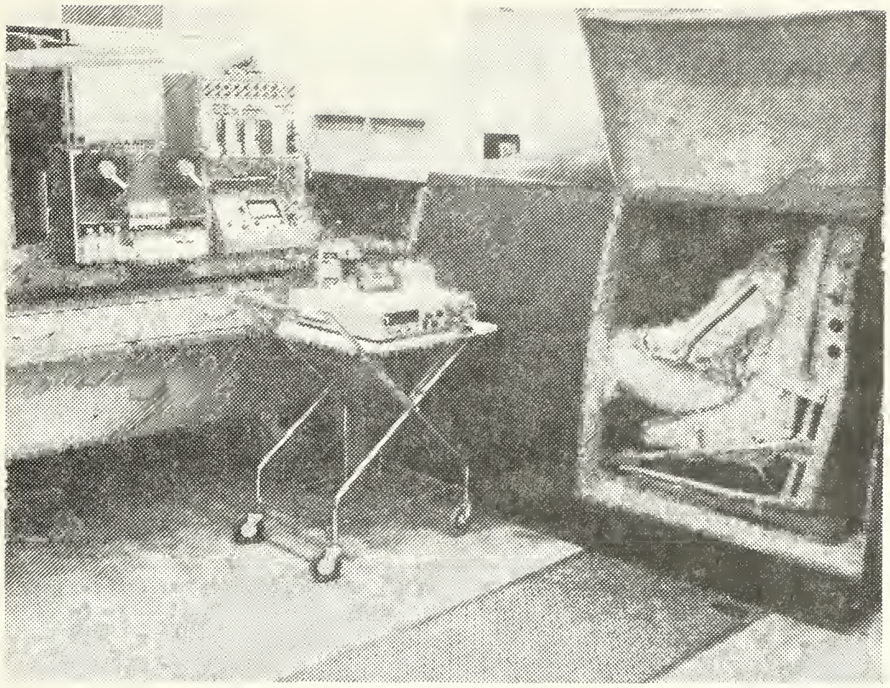

Figure 4. Test Station

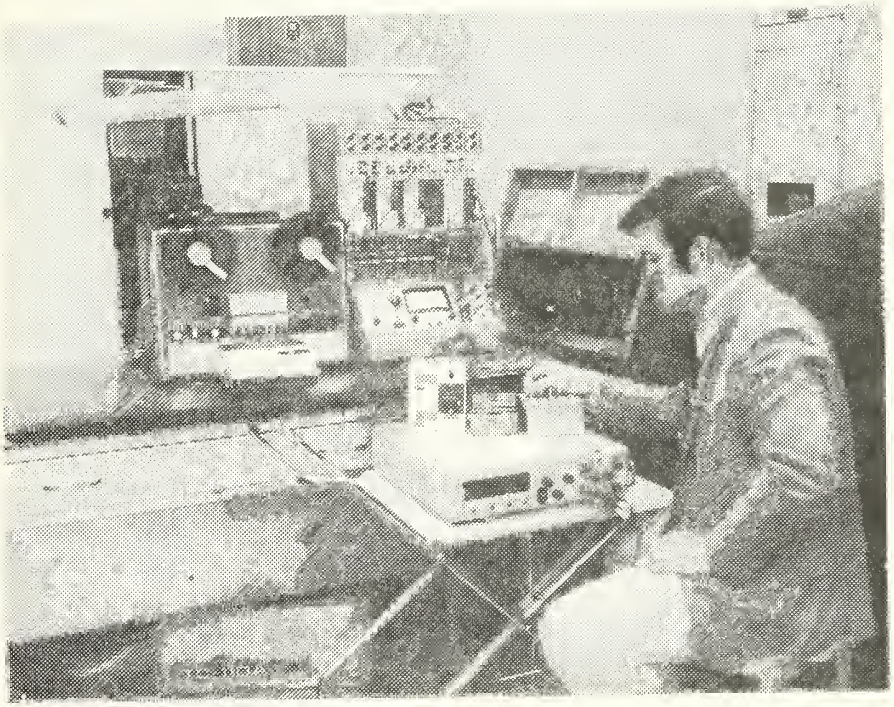

Figure 5. Experimenter's Station.

the center of the grid. The object of each test subject in the tracking task is to keep the pipper inside a "scoring grid," which is a four-square-centimeter area at the center of the oscilloscope. Illumination of the green scorer light provided the indication to each subject that he was "on target," i.e., within the scoring grid.

Inputs to the analog computer are from the stick and the tape as shown in Figures 6 and 7. The scoring principle used in the tracking runs is based upon the cumulative time during a 100-second run that a test subject could keep the pipper within the scoring grid, i.e., the total time in a run that the subject could cancel the pre-recorded tape signal using stick inputs.

Figure 7 shows how the horizontal and vertical tape and stick signals are summed independently. These signals are then amplified by a factor of ten, as shown in Figure 8. The amplified signals are then passed through a sign changing amplifier, and both the original signal and the signal with the reversed signs are fed to diodes which allow current flow in only one direction when a selected voltage is exceeded.

The increase in signal magnitude was required to activate the diodes, which require a minimum of one-half volt before passing current. The sign changing amplifiers are necessary so that both plus and minus signals will trigger the compensator, which is biased for signals of one polarity.

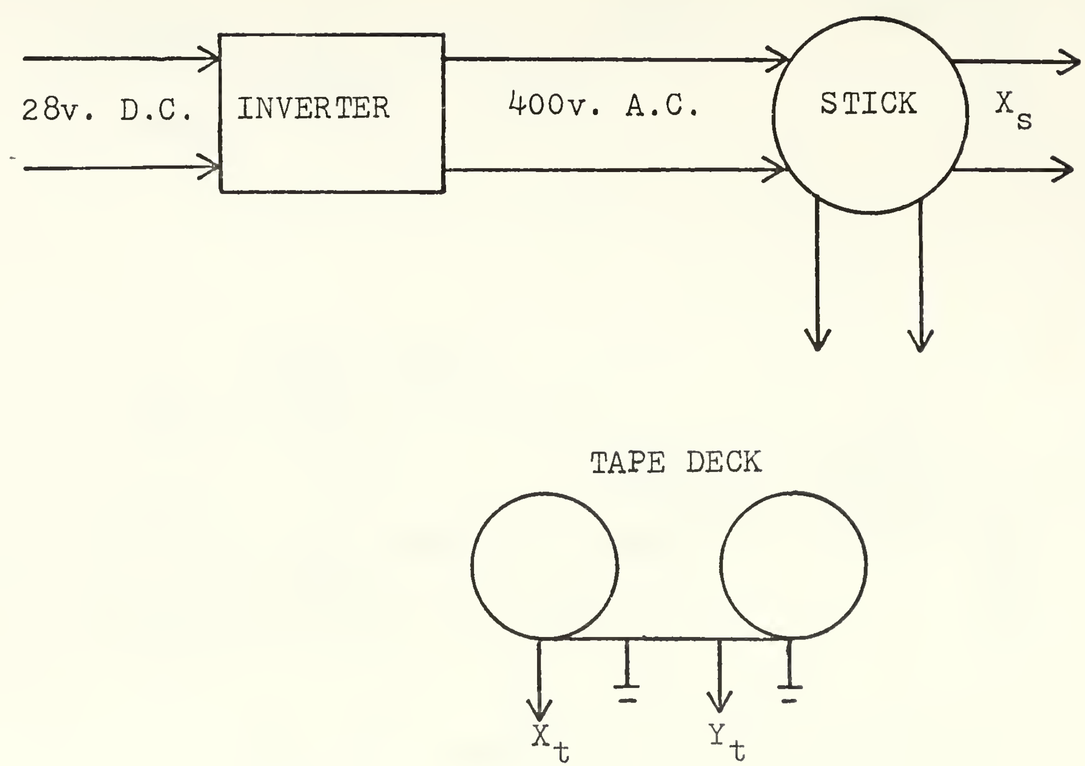

Figure 6. Power Source, Stick Input, and Tape Input.

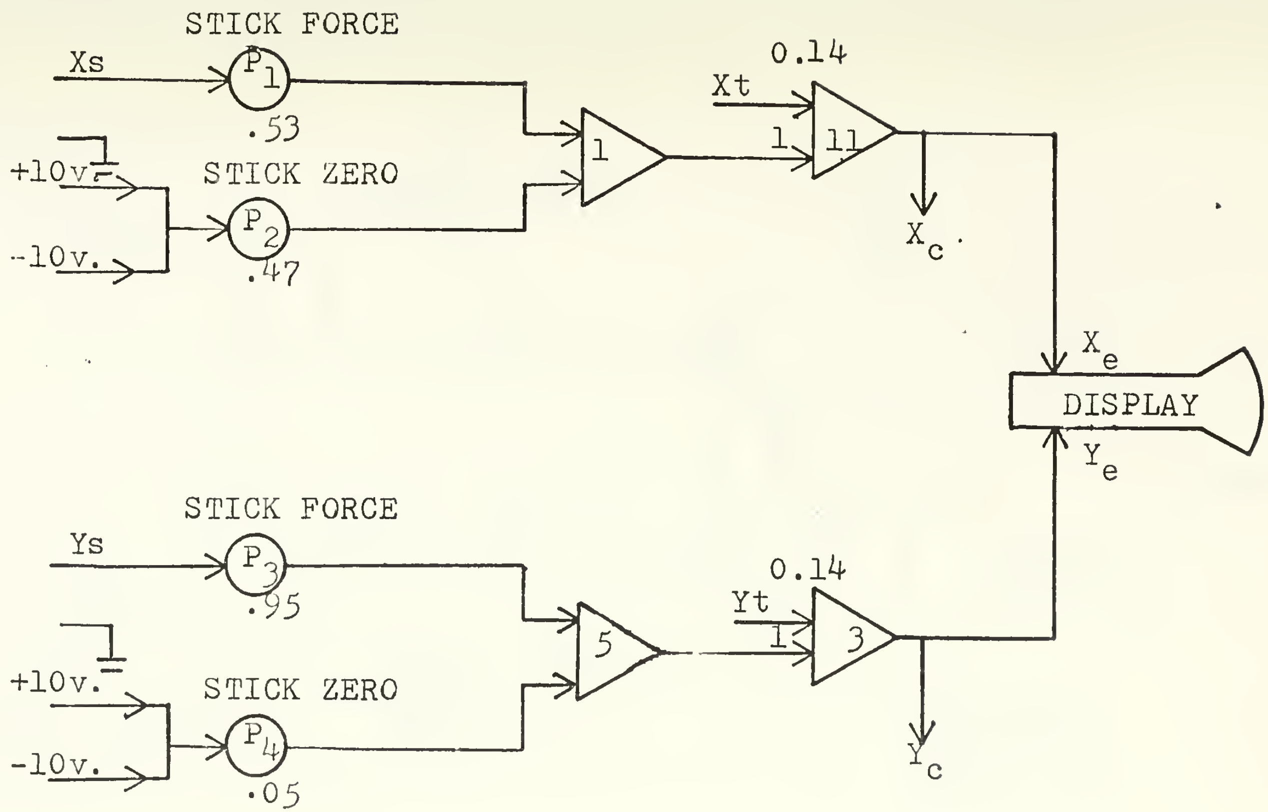

Figure 7. Tracking Task Analog Circuit.

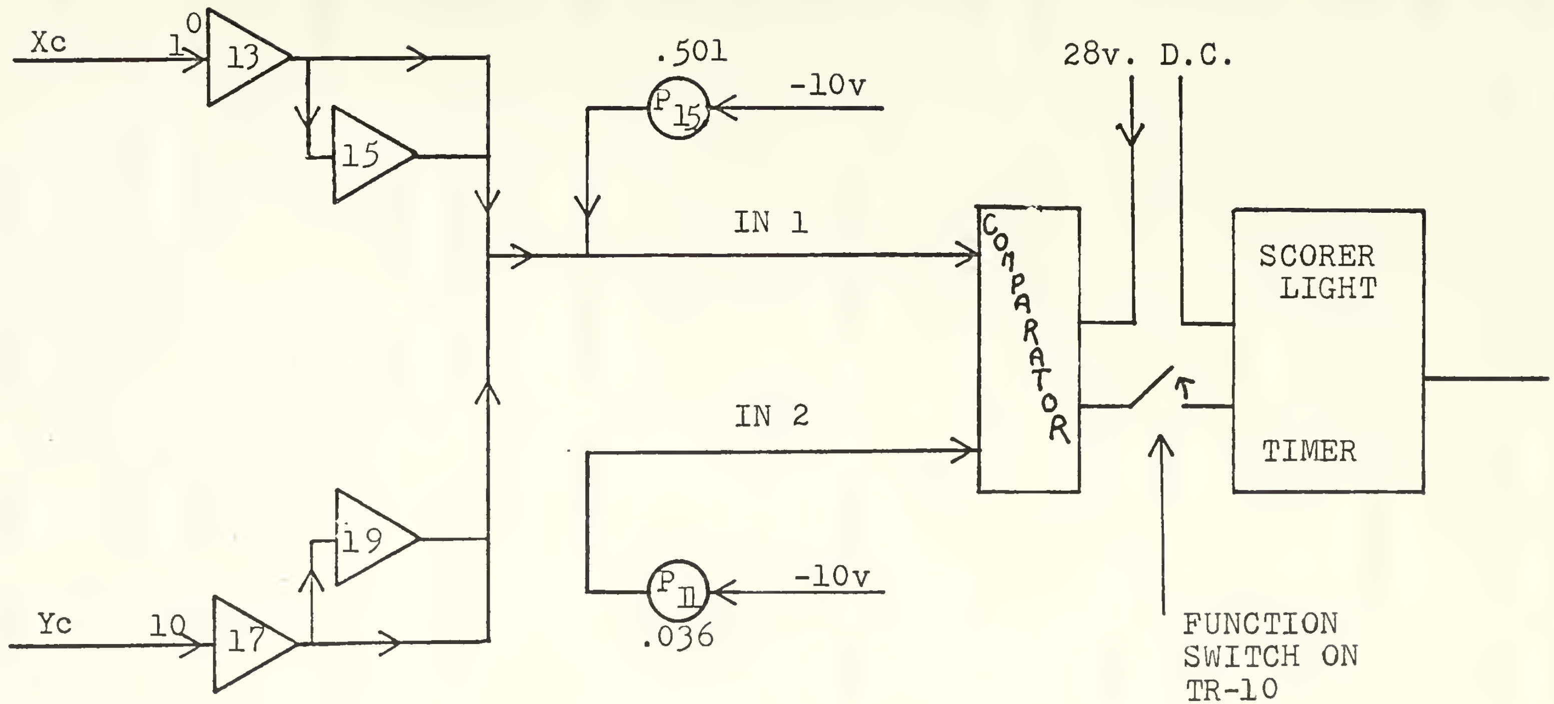

Figure 8. Comparator Circuit.

A bias of -0.5 volts is patched to the output side of the diode bus so that when any summed, amplified signal exceeds this level, the diodes will permit the current flow to the signal comparator input 1N1 terminal. An input of -0.36 volts is patched to the 1N2 terminal of the comparator to provide a comparator bias signal base. The 1N2 input may be varied to adjust the size of the scoring grid on the oscilloscope.

The comparator relay connects the output of a ten-hertz oscillator to the electronics counter so that when the summed signals (either horizontal or vertical) exceed a specified level, the oscillator signal to the counter ceases. Since the counter records the ten-hertz oscillations, the electronic counter records the time that the summed signals (both horizontal and vertical) are within the scoring area to the nearest tenth of a second. The comparator relay also activates the green scorer light on the display panel, which advises the test subject that he is on target.

The entire comparator is activated by a function switch on the analog computer.

Figure 9 is a wiring diagram which depicts the entire apparatus for the secondary task. By properly selecting the position of a toggle switch on his panel, the experimenter is able to complete a circuit which includes a light on his panel, a light and a toggle switch on the test subject's panel, and the Navy

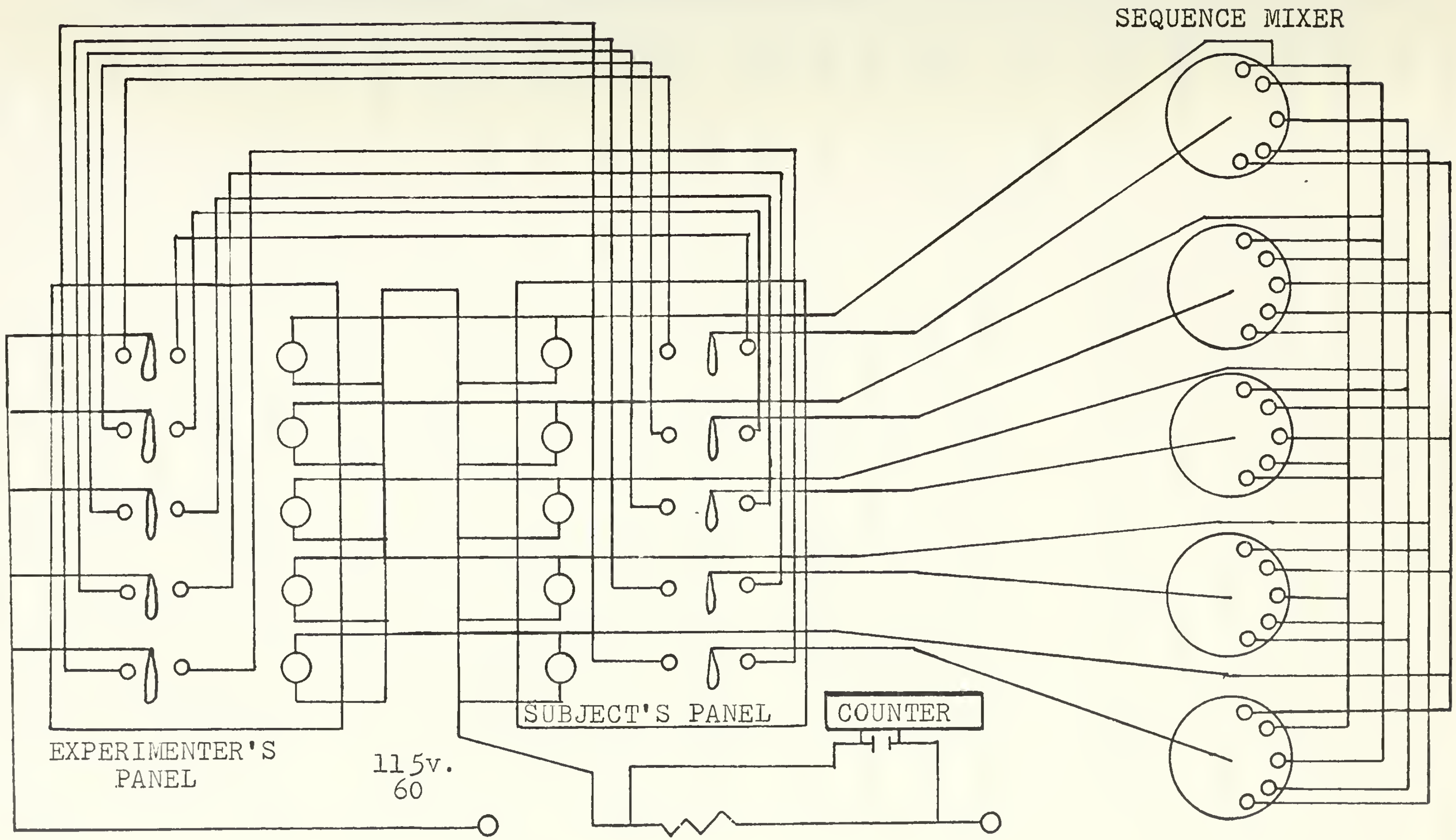

Figure 9. Light/Switch Device Circuit.

universal counter. Whenever any circuit is completed, the counter accumulates digits at a rate of 60 per second. The circuit can be interrupted by the test subject if he moves the proper toggle switch on his panel, thus deactivating the circuit. The sequence mixer at the right of Figure 9 allowed the experimenter to select the appropriate light/switch sequence.

D. PROCEDURE

All testing was completed in four sessions with each test subject. During the first three sessions (learning sessions) each subject performed only the tracking task; the fourth session was reserved for time-sharing performances.

Before the first session began, each subject received the same taped instructions (Appendix A). He was given an opportunity to ask questions before the session began and was free to ask questions at any time during the session. Each of the first three sessions was divided into seven scoring runs; each run lasted 100 seconds. He was allowed a 100-second rest period between each tracking run.

Subjects were allowed to center the pipper and check the size of the scoring grid prior to each run. When the subject was ready to begin, he so informed the experimenter, and then waited for the blue timer light to illuminate. Illumination of the blue light was a signal to the test subject that he should begin

tracking because the comparator, or scoring grid, would be activated in five seconds. The subject continued tracking until the blue light went out. The entire sequence was repeated until the session was finished.

The second and third sessions (usually completed on separated days) were the same as the first session except that the taped instructions were not repeated.

During the first three sessions the experimenter recorded the tracking scores on each run. The scores of all subjects were open to public scrutiny.

Before the fourth session began, each subject listened to the taped instructions for the secondary task (Appendix A). He then completed eleven tracking runs. The first run was in the tracking task alone, but each of the last ten runs was in a time-sharing mode.

Each of the five light sequences was presented twice, each in SPR10 and once in SPR20. Figure 3 (explained in the Design section) is an illustration of the five different light/switch sequences. The SPR/light sequence combinations were presented to each student in a predetermined randomized order. The order in which light stimuli were presented in each run was also randomized.

The first run in the fourth session, a tracking-only run, was completed to ensure that the subject was capable of scoring close to his MTS.

After the first run and prior to all time-sharing runs, all lights on the display panel were illuminated.

From the time that the lights came on each subject had 50 seconds to familiarize himself with the light and switch sequence for that run. At the end of the scoring run, he recentered the scoring grid, signaled the experimenter, and waited for the blue light.

The scoring grid and first light in the secondary task were illuminated simultaneously. The second light was illuminated either five or ten seconds later depending on the SPR.

At the end of each 100-second run the experimenter recorded the tracking score, the total reaction time, and the number of incorrect responses made during the run.

A new light sequence was then selected, and the procedure repeated itself until the session was completed.

III. RESULTS

Raw data were reduced as follows:

A_i = Groups

i=1 (Single-person-crew jet pilots)

i=2 (Two-man crew jet pilot)

i=3 (Helicopter pilot)

i=4 (Propeller aircraft pilots)

B_i = Tracking Score

i=1 (In SPR10)

i=2 (In SPR20)

$(\text{Tracking Score})_i = (\text{MTS}) - (\text{MTS})_i + 100$

C_i = Efficiency Score

$= (1/5) \sum_{i=1}^{5} ((\text{Reaction Time}) + K\ (\#\text{Incorrect Responses}))$

i=1 (in SPR10)

i=2 (in SPR20)

$$K = \frac{\#\text{incorrect responses made in all runs}}{\text{Total Time-sharing Runs Completed}}$$

$D_i = (B_i + C_i)$ = Efficiency Score Plus Tracking Score

(These scores were normalized to a mean value of 100 and a standard deviation of 15 before they were added.)

Table I presents the analysis of variance (ANOVA) summary table for analysis of significant differences in performance (on the tracking task scores in the time-sharing modes) between pilot groups and conditions

Source Of Variance	Sum	Degrees of Freedom	Mean Square	F	P
A	115.9	3	38.6	1.294	Insignificant
B	476.8	1	476.8	15.968	0.0001
A X B	24.6	3	8.2	0.275	Insignificant
Block	241.5	7	34.5		
Error	746.5	25	29.9		
Total	1605.3	39			

TABLE I: 4 X 2 Randomized Block Factorial ANOVA Summary Table for Analysis of Pilot Type Groups (A) and Tracking Scores In Conditions SPR10/SPR20 (B).

SPR10/SPR20. No significant differences were found except due to SPR conditions ($p < 0.001$).

Table II presents the ANOVA summary table for analysis of pilot type groups (A) and efficiency scores under conditions SPR10/SPR20 (C). No significant differences were found except due to SPR conditions ($p < 0.001$).

Table III presents the ANOVA summary table for analysis of pilot type groups (A) and combined tracking and efficiency scores under conditions SPR10/SPR20 (D). No significant differences were found except due to SPR conditions ($p < 0.001$).

Table IV presents the ANOVA summary table for analysis of pilot type groups and total reaction time under five levels of difficulty. Effects on performance due to type group, conditions of difficulty, and the interaction of groups and levels of difficulty were significant. The Duncan multiple range test for difference between groups indicated that total reaction time for group 2 was significantly longer, than for the other groups ($p < 0.05$). (See Figure 10). The Duncan multiple range test for total tracking scores under the five levels of difficulty indicate that each level was significantly different from each other level ($p < 0.05$) except for level 2 and level 5. (See Figure 11.)

The significant interaction between groups and levels of difficulty are represented in Figure 10. Group 2 was the slowest at all levels, with the difference

Source of Variance	Sum	Degrees of Freedom	Mean Square	F	P
A	205.0	3	68.3	2.737	Insignificant
C	2757.3	1	2757.3	110.480	0.0001
A X B	60.3	3	20.1	0.805	Insignificant
Block	47.6	7	6.8		
Error	623.9	25	25.0		
Total	3694.0	39			

TABLE II: 4 X 2 Randomized Block Factorial ANOVA Summary Table for Analysis of Pilot Type Groups (A) and Efficiency Scores Under Conditions SPR10/SPR20 (C).

Source of Variance	Sum	Degrees of Freedom	Mean Square	F	P
A	1610.1	3	536.7	1.778	Insignificant
D	17871.8	1	17871.8	59.22	0.0001
A X D	184.7	3	61.6	0.20	Insignificant
Block	1937.9	7	276.8		
Error	7544.7	25	301.8		
Total	29149.2	39			

TABLE III: 4 X 2 Randomized Block Factorial ANOVA Summary Table for Analysis of Pilot Type Group (A) and Efficiency and Tracking Scores Under Conditions SPR10/SPR20 (D).

Source of Variance	Sum	Degrees of Freedom	Mean Square	F	P
Total	3532.9	99			
Between Subjects	1294.2	19			
Gorups	527.8	3	175.9	3.673	0.05
Error Between	766.4	16	47.9		
Within Subjects	2238.7	80	28.0		
Difficulty Levels	803.7	4	200.8	13.66	0.001
Diff. Levels X Groups	494.8	12	41.2	2.8	0.005
Errors Within	940.6	64	14.7		

TABLE IV: 4 X 5 Mixed Factorial, Repeated Measures on One Factor for Analysis of Pilot Type Group and Total Reaction Time Under Five Levels of Difficulty.

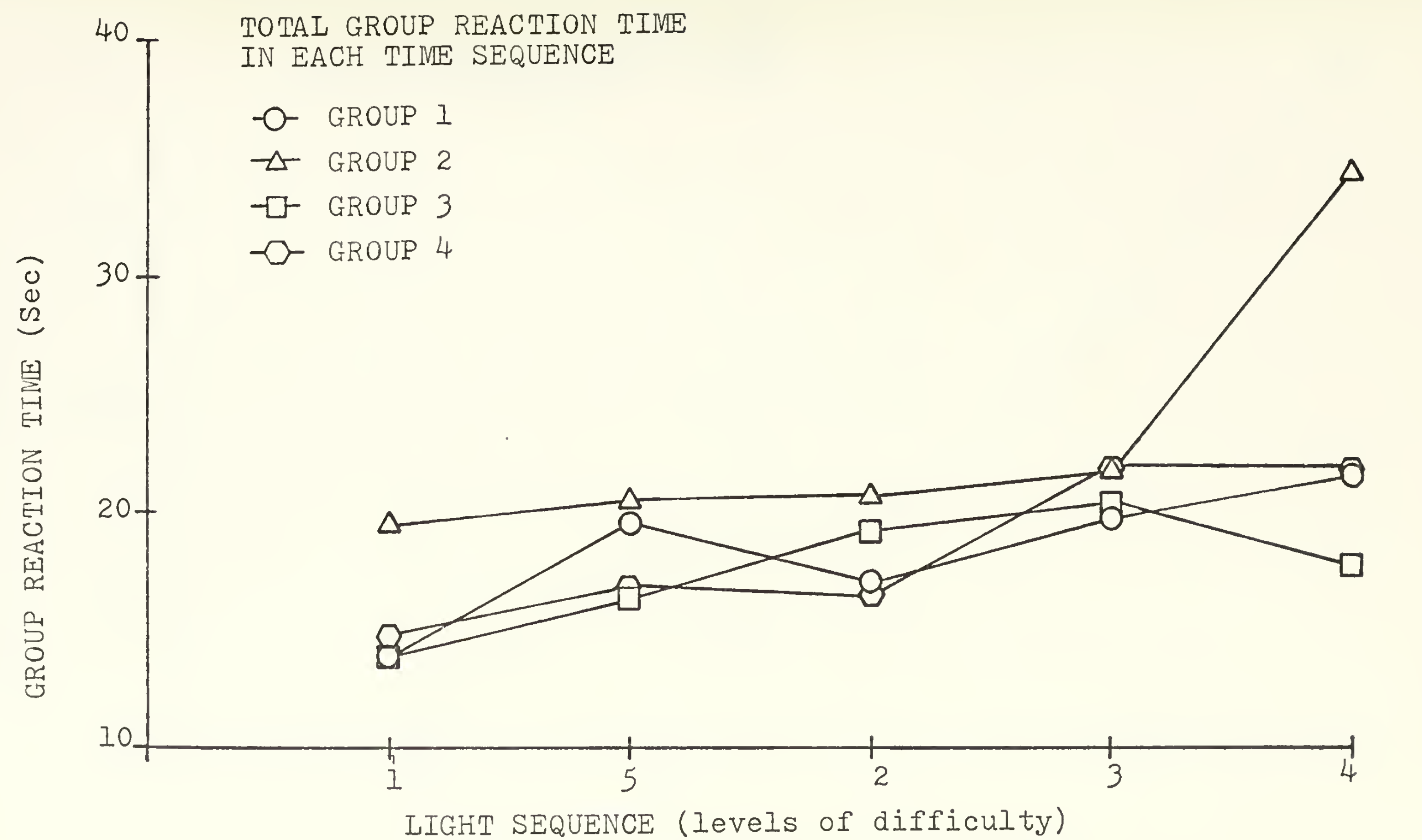

Figure 10. Interaction Between Pilot Type Groups and Total Reaction Time Under Levels of Difficulty.

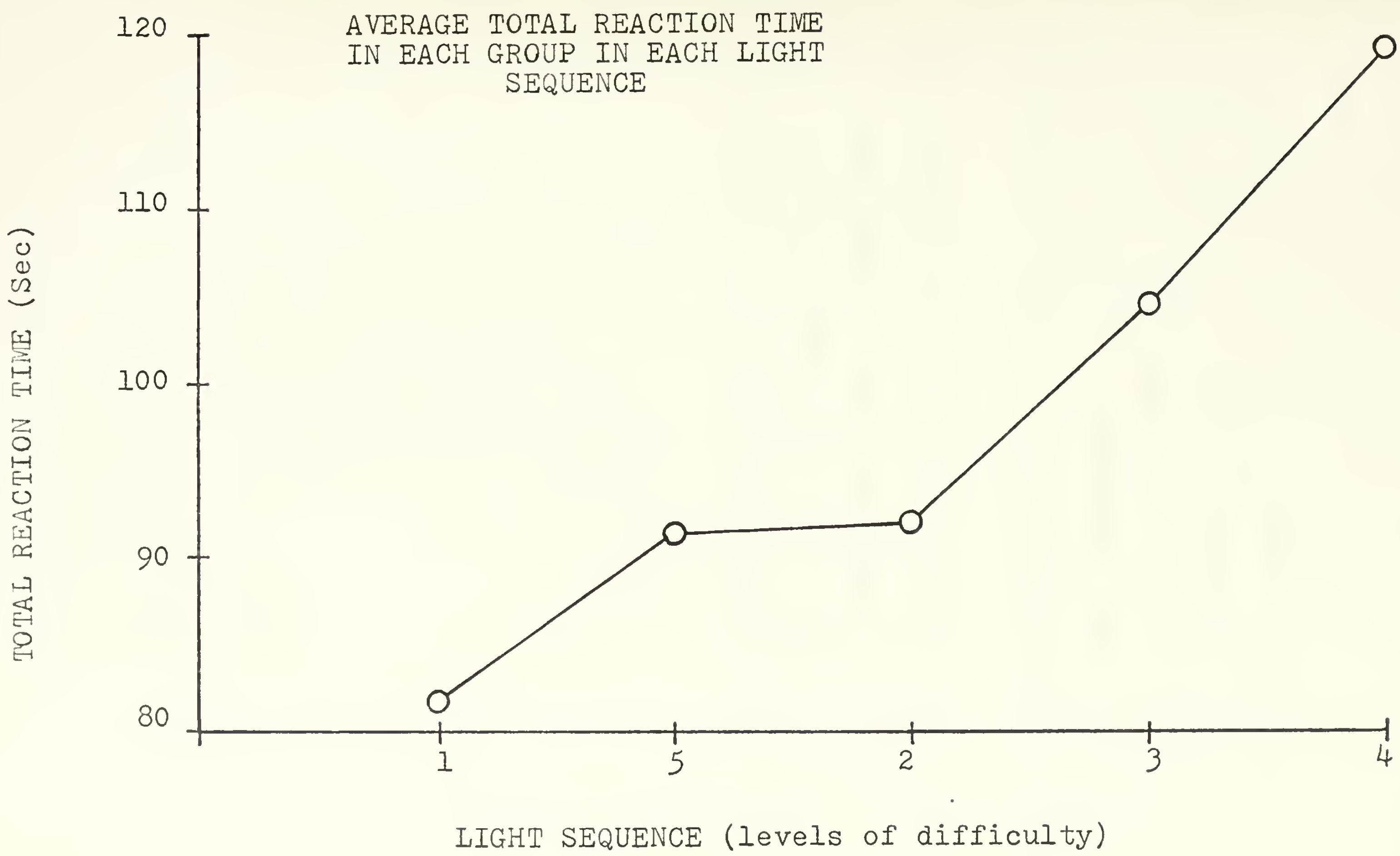

Figure 11. Average Reaction Time of Groups Under Levels of Difficulty.

between groups being the greatest at the most difficult level (level 4). Group 1 was apparently slower than group 3 at difficulty levels 4 and 5. Group 3 was apparently slower than groups 1 and 4 at level 2, but faster than all other groups in level 4.

The present results may be suspect due to a relatively small number of subjects per group. Also the group differences were found only with the variable of total reaction time on the secondary task. No group differences were found with efficiency scores or tracking scores.

Four separate rank order correlations were performed. The rho between MTS and MTS10 rankings was 0.386. The rho between MTS and MTS20 was 0.364. The rho between MTS10 and C_1 was 0.486, and between MTS20 and C_2 was 0.124.

IV. DISCUSSION

The analyses of variance presented in Tables I, II, and III indicate that performance under SPR20 was significantly degraded as compared to SPR10. This finding is logical in that one would expect decreased performance as task load increased. It is interesting to note that there were no significant differences due to pilot type from helicopter to propeller to fighter/attack pilot groups.

The more interesting results came from an interpretation of the correlation coefficients. A rho of 0.386 and 0.364 between MTS and MTS10/MTS20 respectively tend to indicate that 13½% of the variation in performance in MTS is accounted for by the same task under SPR10/SPR20 when performed in a time-sharing mode. This indicates that the ability to predict performance of the same group on tracking time-sharing performance from tracking non-time-sharing performance is very poor. The findings tend to support the contention that methodologically the prediction of complex performance elements (such as tracking scores) should not be attempted except within the context of the total time-sharing task environment. Implications may extend to the area of complex task training. Possibly training on tasks such as tracking should be conducted within the

total time-sharing task context (see Gabriel and Burrows, 1968).

The rho correlation coefficients between MTS 10 and efficiency scores on the secondary task was 0.486. The rho between MTS20 and efficiency scores in the secondary task was 0.124. The difference in correlations tends to show that the more complex situation of MTS20 is less predictive of efficiency scores. This may indicate that the more complex a task becomes, the greater the necessity to measure all task elements in a time-sharing analog to the real world task.

It would be of interest to conduct studies with a secondary task which is more operationally relevant to time-sharing with tracking tasks. Further areas of interest would be studies of portions of real world flight tasks which require time-sharing of more than two tasks. The present experiment could be continued with changes in the type of stimulus used in the secondary task. The effects of environment (heat, noise, vibration, etc.) on time-sharing performance could be studied. Experimenters could also evaluate the transfer of complex performance training in a simulator to actual system operation. The more ambitious experimenter could develop methodology for dual or multiple person crew complex performance testing.

APPENDIX A

TAPED INSTRUCTIONS FOR TEST SUBJECTS

Preliminary Phase.

"You are seated in the Research Education Device for Basic Aeronautics, also known as the RED BARON. The only equipment that you need to be familiar with at this time are the non-moving force stick on your right, the oscilloscope screen in front of you, the blue and green lights on the upper portion of the display panel. and the two adjustment knobs on either side of the airspeed display. Do not place your fingers behind the display panel; there are some exposed wires there which could shock you.

There is a green dot of light on the oscilloscope. When the scoring run begins, it will move around the scope in a random track. Your mission, should you decide to accept it, will be to keep the dot on a target that is located in the center of the oscilloscope. You will be on target whenever the green light is lit. You will be able to control the dot by applying pressure to the non-moving force stick.

You may find it easier to consider yourself to be flying the grid, and to think of the dot as a target toward which you are flying. If the dot moves up, you can bring it back to the center by pulling back on the

stick. If it moves down, push forward on the stick, and so on.

The testing session will consist of seven runs, each lasting 100 seconds. Your score on each run will be the total time you are on target divided by the 100 seconds.

To compensate for a lack of reality a high degree of difficulty has been built into the tracking task. Part of this difficulty is the amount of force required in the non-moving force stick. It is expected that your arm will become tired: for this reason you are asked not to touch the force stick unless the blue light is on.

The blue light will come on five seconds before each scoring run begins, and will go off at the end of each run. When the blue light goes off, let go of the stick, wait for the pipper to stop moving, and then recenter it if it is not in the center of the grid. Then check the size of the scoring grid by moving the force stick very slightly in all directions. The green light should go out whenever the pipper reaches a distance of about one millimeter from the center of the scope.

When this has all been completed, kick the side of the RED BARON two times. Shortly thereafter the pipper will jump to the upper right corner of the scope and then come back to the center. While all this is happening, you need only sit back and wait for the blue light to come on.

If you have any questions about procedures during the test session, tap the overhead three times to get my attention. So the code is: knock three times on the ceiling if you want me, twice on the side if you're ready to go.

Do you have any questions?

The testing session will begin shortly."

Time-Sharing Phase.

"During this session you will be asked to perform an additional task inside the RED BARON. After your second run you will see all of the lights on the left side of the display panel illuminate. You will be able to turn them off with the toggle switches located next to the lights. The same switch, however, will not always turn out the same light. Before each run begins, you you must determine which switch corresponds to which light. The sequence will then remain constant until the end of that run. Before the next run begins, you will have the same opportunity to learn the same light and switch sequence.

So this is what will happen today: You will perform only the tracking task during your first and second runs. Before the third run begins, turn out the lights which have been turned on remembering which switch corresponds to which light. When the green light comes on, place all toggle switches in the same position, and don't touch them again until the scoring run begins.

Recenter the scoring grid, and check it for size. When you are ready to begin, knock two times as before. Then just wait until the blue light comes on.

When the blue light comes on, you must simultaneously perform the tracking task and turn out the lights. A light will come on at the beginning of each run and either every five seconds or every ten seconds thereafter until the 100 seconds is completed.

You are asked to perform each task as accurately and, in the case of the light-switch task, as rapidly as possible. You are cautioned that mistakes in the light-switch task bring a heavy penalty. You are also cautioned that the toggle switches must be moved gently with only the thumb and forefinger or else the scoring grid will be dislocated.

Please do not hesitate to stop the session at any time if you have a question.

Do you have any questions at this time?

Good luck."

APPENDIX B

LIST OF EQUIPMENT

1. Analog Computer - Electronics Associates, Inc.

   Pace TR-10 Model 7350

2. Tape Deck - Midwestern Instruments

   ALPHA-434

3. Navy Universal Counter - Dyna Sciences Corporation

   CP-929/USN-245A

4. Timer - Hayden Corporation

   Counter/Timer, Electromechanical

5. Timer - LAB-LINE Instruments, Inc.

   LAB-CHRON Timer, No. 1402

6. Cathode Ray Tube - Dumont Corporation

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